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EFFECT OF SAMPLE SIZE ON EVALUATION OF MIXING QUALITY OF FINELY DISPERSE POWDERS

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Some researchers working in the field of the mixing of powder materials acknowledge the influence exerted by the sample size of a mixture on the actual evaluation of mixing quality. In the literature, however, there is no complete procedure for either theoretical or experimental comparison of samples that differ in size from batch to batch with the same components and proportions of their content in the mixture [1, 2].

The size of the sample should be appreciably smaller than the size of the batch formed from a powder mixture; moreover, it should be compared with the size of the functional microcell in which all particles of the components exist in a given proportion. The number of samples should represent rather completely the general population of the mixture being tested. Correct evaluation of the mixture can be guaranteed only with such testing of the mixture. It is natural that similar testing requires significant effort and time.

During actual industrial production, however, it is possible to convert the testing of each powder mixture into a long-term research study; for practical purposes, therefore, an attempt has been made to compare experimentally and theoretically samples of different size from different batches with the same components and same proportions of their content in a mixture.

The formula of the theoretical standard deviation σ for the completely disordered equilibrium state of a two-component mixture, which is proposed in [3], is adopted as the basis for solution of the problem in question:

$$\sigma = P^{0.5}(1 - P)^{0.5}n^{-0.5}, \tag{1}$$

where P is the proportion of component content in the mixture, which is equal to the mathematical expectancy of the proportion for a binomial distribution, and n is the number of particles in the sample.

Formula (1) reflects rather completely the stochastic nature of the mixture preparation, since independent, but combined events are evaluated, and an inverse proportional dependence on n is logical, and makes it possible to improve the authenticity of the event, since it goes over into the facet of work with a general population.

It is necessary to transform the number of particles n, which is accepted in practice with some difficulty, to a quantity convenient for study, and to impart to formula (1) a dimensionless (relative) character, which is possible if the coefficient of variation is assigned as a heterogeneity indicator [4].

The following expression is derived as a result:

$$V_1 = V_2 q_{(2-1)}(Q_2/Q_1)^{0.5}, \tag{2}$$

where V_1 and V_2 are heterogeneity factors of the mixture for samples Q_1 and Q_2, respectively, in %, $q_{(2-1)}$ is a dimensionless complex correct factor for the ratio Q_2/Q_1, and Q_1 and Q_2 are comparable samples in g.

The actual values of $q_{(2-1)}$ will fall between the limiting values $q'_{(2-1)} = 1$ and $q''_{(2-1)} = (Q_1/Q_2)^{0.5}$, and are given in Table 1 for a two-component (Fe + Zn) powder mixture with concentration ratios of from 1:1 to 3:1, and size ratios ranging from 1:24 to 24:1 for the samples taken.

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TABLE 1

Q_2/Q_1	Limiting theoretical value of $q''_{(2-1)}$	Experimental value of $q''_{(2-1)}$
1/24	4.90	2.50
1/16	4.00	2.23
1/12	3.46	2.05
1/8	2.84	1.82
1/6	2.45	1.68
1/4	2.00	1.49
1/3	1.73	1.37
1.2	1.42	1.22
2/1	0.705	0.82
3/1	0.579	0.73
4/1	0.500	0.67
6/1	0.410	0.60
8/1	0.355	0.55
12/1	0.280	0.48
16/1	0.250	0.45
24/1	0.204	0.40

The explicit relationship between the theoretical values of the coefficient $q_{(2-1)}$ and the ratio of sample sizes, and the dimensionless character enable us to present it in the following form:

$$q_{(2-1)} = (Q_2/Q_1)^y, \tag{3}$$

where y is an exponent (determined experimentally).

From expressions (2) and (3), we obtain

$$V_1 = V_2(Q_2/Q_1)^z, \tag{4}$$

where $z = y + 0.5$.

Zinc and iron powders (the range of particle dimensions is less than 160 μm for both powders) were taken in a testing program for the continuous batching of a two-component mixture.

Table 1 presents limiting theoretical values of $q''_{(2-1)}$ from formula (2), and experimental values of $q''_{(2-1)}$ when $y = -0.289$ [$z = 0.211$, see expression (5) below].

The value of the exponent z was established experimentally, and the law governing the distribution of its general population consisting of 1920 samples from different batches with the same components and same ratios of their content in the mixture was evaluated by comparing it with a normal distribution using the compliance criterion χ^2.

In the majority of cases, the experimental distribution of z values deviates little from the normal distribution; in certain cases, however, a large concentration of z is observed about its mathematical expectancy (the theoretical probability of values about the mathematical expectancy is 0.38–0.40 according to normal-distribution law, and is 0.60–0.64 according to the experimental distribution).

The studies that we conducted made it possible to ascertain the trend in the variation of the exponent z: as a rule, smaller z values are obtained in mixture samples having a rather small (less then 160 μm) range in particle size of the components, and with larger sizes of comparable components. As a result, it is possible to cite some results regarding the evaluation of the exponent z: the mathematical expectancy of z based on processing of all experiments is 0.211 with a standard deviation equal to 0.0549, and coefficient of variation of 26%. This z value can be referred to as a stable characteristic of its general population.

As a result, the following formula can be recommended for practical production calculations as applies to finely disperse materials of a two-component mixture:

$$V_1 = V_2(Q_2/Q_1)^{0.211}. \tag{5}$$

Experimental data gathered by several other authors were processed in accordance with the procedure in question. Poll et al. [5] obtained experimental data on the mixing of finely disperse powders employed in uranium production: uranium oxide and thorium oxide in various proportions with nickel (from 10:1 to 100:1) and with different sizes (0.05–1 g) of samples taken for analysis of mixing quality. Of the six tests analyzed, the exponent $z = 0.200$ in five, and $z = 0.250$ in the other test. Lomakin [6] studied the mixing of coarsely disperse polyethylene spheres (less than 4 mm) with different ratios of concentrations and sizes of samples extracted (4–6 g). Four experiments processed in accordance with the proposed procedure yielded a z value of 0.460 in three cases, and 0.480 for one test.

The many years of experience gained by the author suggest the validity of formulas (4) and (5). Naturally, the value of the exponent $z = 0.211$ is not universal for many dual-component mixtures and various component ratios, but, it is possible that other researchers can make use of the proposed procedure in evaluating the quality of powder mixtures.

If needed, the author is willing to provide methodical assistance at telephone No.: (095) 286-24-28

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